EVALUATING ACADEMIC READINESS FOR APPRENTICESHIP TRAINING

Revised for

ACCESS TO APPRENTICESHIP

SCIENCE SKILLS
ENERGY

AN ACADEMIC SKILLS MANUAL
for
The Precision Machining And Tooling Trades

This trade group includes the following trades:
General Machinist, Tool & Die Maker,
Mould Maker, Pattern Maker, and
Machine-Tool Builder Integrator

Workplace Support Services Branch
Ontario Ministry of Training, Colleges and Universities

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In preparing these Academic Skills Manuals we have used passages, diagrams and questions similar to those an apprentice might find in a text, guide or trade manual.

This trade related material is not intended to instruct you in your trade. It is used only to demonstrate how understanding an academic skill will help you find and use the information you need.

SCIENCE SKILLS
ENERGY

An academic skill required for the study of the Precision Machining and Tooling Trades

INTRODUCTION

Everything that happens in the shop depends on a transfer of energy. When you turn a screwdriver, you transfer energy from your arm to the screw, causing it to move. An electric drill uses electrical energy instead of muscular energy to do the work. The electrical energy might be generated at a hydro-electric dam. When water flows over a dam, the energy contained in the moving water can be harnessed to create electrical energy. In these examples, the application of energy results in some kind of movement.

Energy is the basis of all motion – of everything that happens or changes. A description of energy requires the use of several basic scientific terms, including *force, motion, work and power*. You probably have a general sense of what each of these terms means.

For example, you follow regulations to ensure that the project you are working on can withstand the different forces that will be exerted on it. When a hoist lifts a heavy machine into place, you are aware of the power of the hoist and the motion of its load. You have a good concept of what work is after a day on the job and you also appreciate that your power tools do a lot of the work for you.

In the machining trades, you work with machines that provide the energy to complete a job efficiently and safely. You constantly use machines to convert one kind of movement into another kind. Simple machines, such as the lever you use to move a drill press into its final position, get their energy from human muscle power. Complex machines, such as those used in the tooling shop, get their energy from the chemical energy stored in gasoline or electricity.

All aspects of work involve using energy to accomplish whatever needs to be done. Understanding the definitions of force, energy and work provides a picture of how all the forces that apply in your job situation are interrelated.

This skill sheet looks at the scientific meaning of these terms. The following concepts are covered:

- Motion, energy and force
- Work and power
- Energy and its transformation
- Transfer of energy at the mechanical level
- Conservation of energy

MOTION, ENERGY AND FORCE

Just about everything that happens to an object is described scientifically in terms of its motion. ***Motion** is described as a continuing change of place or position.*

Motion occurs when a force is applied to an object that is free to move.

- During your work day, you move many different objects. You might carry sheets of metal and the bolts you are using to hold them together to where they are being used. You might drive in rivets or operate laser cutting equipment.

*A **force** is something which changes the* **motion** *or position of an object.* A force is felt by the object as a push or pull. An applied force results in the transfer of energy.

- When you turn on a power saw, electrical energy is transferred to the motor, causing it to rotate. The motor in turn drives the blade of the saw, causing it to move through a metal rod.

- When a dam is opened, the water moves downwards, or changes its position because the force of gravity pulls it. The energy of the moving water exerts a force on the blades of a turbine, causing them to move. As the water moves through the turbine, some of the motion of the water is transferred to the blades of the turbine.

The units commonly used to measure force are the ***newton*** (n or nt) in the metric system and the ***pound*** (lb) in the imperial system. These units are the same as the units of weight. ***Weight*** is the measure of one specific force, that of the earth's gravity, on the ***mass*** of an object.

The ***mass*** of an object is the amount of matter it has. Because objects have mass, they resist being moved. This resistance to being moved is called ***inertia***. It is because objects have inertia that a force must be applied to get them moving and to keep them moving.

WORK AND POWER

Work is closely related to force. When a force is applied to an object, the object feels a push or pull. Usually an applied force results in the object moving, which means that the object has increased ***kinetic energy***, or energy of motion.

In some cases, the force is too weak to overcome the object's inertia and so it doesn't move. The applied force is stored as ***potential energy***.

- The water contained behind a dam has potential energy. When potential energy is released, it is converted to kinetic energy.

A force applied to an object can result in the object gaining either kinetic energy or potential energy. Work is the measure of any force that actually results in movement.

Work *is defined as a force exerted over a distance*. The formula for work is:

work = force x distance

or

W = Fs s is distance

Whenever something moves because of an applied force, work has been done.

- Work is done when water flows over a dam to a lower level.
- Work is also done when an electric motor turns the blade of a power saw or when gasoline is burned to turn the wheels of a vehicle.

Since force can be measured and the distance an object moves can be measured, we can calculate the amount of work done. In the metric system, the unit of work is the ***joule*** (J). In the imperial system, the unit of work is the ***foot-pound*** (ft-lb).

Torque is a twisting or rotating force. It is the turning force that keeps the crankshaft rotating. It is a measure of an engine's ability to do work.

- Torque is the force that pushes on the crankshaft and causes it to turn. It results from the force of the piston being transferred to the connecting rod. The rod acts as a lever, transferring the up and down motion of the piston to the turning motion of the crankshaft.

Torque is calculated by multiplying the amount of force applied by the distance it is applied over. This distance is the length of the lever or connecting rod. The units of torque are pound-feet or joules.

Power *is the rate of doing work.* Power depends on the amount of work (W) done, divided by the time (t) required.

Example: Two electric motors need to move two 50 lb loads on two different conveyor belts a distance of 100 feet. The first of the two motors is very small, and will take several minutes to move the load. The other belt, however, is run by a larger motor, and will therefore be able to move the load in only a few seconds.

Both motors do the same amount of work; however, because the second motor did the work in less time it has more power.

The formula for power is:

$$\text{Power} = \frac{\text{Work}}{\text{time}}$$

or

$$\text{P} = \frac{\text{W}}{\text{T}}$$

The metric unit of power is the ***watt*** (w). Because a watt is a small unit, the term ***kilowatt*** (kw), meaning 1000 watts, is often used. The unit of power in the imperial system is ***horsepower*** (hp).

- In an internal combustion engine, work is produced by the expanding gases in the cylinder. The faster this happens, the faster the engine speed and the greater the horsepower.

Electric motors have a horsepower or kilowatt rating indicated on their nameplate. If you need to pick a motor that is the correct size for the job, you look at the horsepower or kilowatt rating of the machine to find out how powerful it is.

ENERGY AND ITS TRANSFORMATIONS

Why have we defined force and work before defining energy? Just as work is defined in terms of applied force, energy is defined in terms of work done.

Energy *is defined as the ability to do* **work** *or to exert a force over a distance.* Energy enables work to be done. (Since torque is a measure of an engine's ability to do work, by this definition it can also be considered the energy of the engine.) Energy might cause work (or change in motion) to be done right away or energy might be stored and released to do work later.

Mechanical energy results from forces acting on objects at the visible level. It is the kind of energy we can see and are familiar with in the everyday world. There are two kinds of mechanical energy:

- ***kinetic energy,*** is moving energy due to an object's motion, and
- ***potential energy***, is stored energy due to an object's position.

Energy at the atomic level

This concept of kinetic and potential energy can be applied at the atomic level. The motion of visible objects is the result of the application of a force.

In the same way, motion at the molecular level is also the result of the application of a force. This force is generated by the negative and positive charges on electrons and protons. Forms of energy at the atomic level include light, heat, sound, magnetic, nuclear, electrical and chemical energy.

- Atoms can store energy as potential energy, particularly as potential electrical energy. The potential energy due to the position of electrons in a grid can later be released to do electrical work.

- Chemical reactions can also release energy. Gasoline has the potential to combine chemically with oxygen, resulting in combustion. The combustion of gasoline in an engine releases energy that can be used to bring about motion in a vehicle. The potential energy stored in gasoline can be released to drive the wheels of a vehicle.

Energy is constantly being transformed from one form to another. Heat energy at the molecular level can be changed to visible mechanical energy. Chemical energy and nuclear energy can create electrical energy.

TRANSFER OF ENERGY AT THE MECHANICAL LEVEL

There is a close connection between potential energy and kinetic energy.

- ♦ Anything that moves has kinetic energy. The total kinetic energy of a moving object is the same as the amount of work done by the object.

- ♦ Potential or stored energy is acquired when an object is moved or held against a force, such as water behind a dam.
  - Work must first be done to an object place to give it potential energy.
    - When air is compressed in a pneumatic tool, work done to compress the air can be released as kinetic energy when the air flows out to operate the tool.
  - When an object with potential energy starts to move, it starts to do work.
    - Its potential energy begins to change to kinetic energy.

Potential energy is the “not yet used” ability to do work. It is like having a force deposited in your account in the bank. At some future time, you can take it out and spend it. Kinetic energy is the spending spree. The force in the bank has been withdrawn and is being used to cause motion.

The unit of potential and kinetic energy is the ***joule***, which you will recall is the same as the unit for work.

> **Example:** If a ball is thrown, it rises in the air with a certain amount of kinetic energy. The kinetic energy gradually gets changed to potential energy as the ball moves against the pull of gravity. At the point where the force of gravity finally stops the upward motion of the ball (the highest point), all the kinetic energy is now converted to potential energy. The ball has no motion but it has lots of potential to fall back down. See Figure 1.
>
> As gravity pulls the ball back to earth, the potential energy is gradually changed back to kinetic energy. Once the ball hits the ground and stops, gravity can no longer cause it to move. All of the kinetic and potential energy has been transferred to the ground.
>
> When the ball is in the air, the amount of kinetic energy it has keeps changing, as does the amount of potential energy. As kinetic energy increases, potential energy decreases; as kinetic energy decreases, potential energy increases. However, the sum of the two energies is equal to the original amount of energy transferred to the ball when it was thrown. Once the ball hits the ground, all the energy is transferred to the ground.

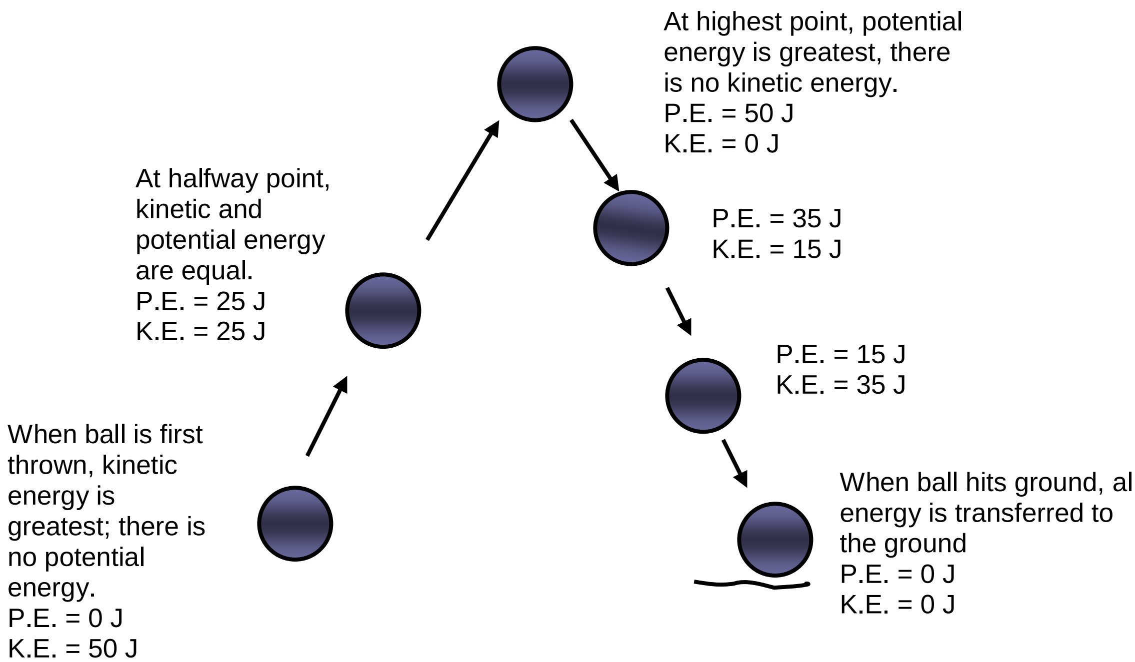

FIGURE 1: Kinetic and Potential Energy are Closely Related

Let's look at what happens to the relative amounts of potential and kinetic energy when a ball is thrown upwards with 50 joules of energy.

- You can see from Figure 1 that the amount of kinetic energy is greatest when a ball is first thrown upwards and also just before it returns to the ground.
- As the ball moves upward against the force of gravity, its potential energy increases at the same rate as the kinetic energy decreases.
- At the highest point in its trajectory (path), it actually stops moving for an instant. At this point, it has its greatest amount of potential energy and no kinetic energy at all.
- As soon as it starts to fall downwards, its potential energy decreases at the same rate as the kinetic energy once again increases.

Your arm muscles did 50 joules of work in throwing the ball. At different times in its flight, the specific amounts of kinetic energy and potential energy vary but the total amount of energy always equals 50 J, until the ball hits the ground.

CONSERVATION OF ENERGY

Energy is never used up or destroyed, *it just changes form and gets transferred around.* When energy changes form, there is the same amount of total energy after the change as before.

This concept is expressed as the ***Law of Conservation of Energy:*** *Energy cannot be created or destroyed, but it can be converted from one form to another.*

We saw this in Figure 1. The ball is thrown with 50 J of kinetic energy. At every point in the trajectory, there is a total of 50 J of energy acting on the ball. This is true until all of the energy is transferred to the ground when the ball hits.

We control the conversion of potential energy to kinetic energy in order to do useful work. However, not all the energy released is available to do useful, mechanical work. Some is changed to other forms of energy.

- When we run a motor using the energy from electricity, not all of the energy released is converted to mechanical work or torque.
  - Some of the energy is lost as heat and sound because of friction.

- When we turn on a light, some of the electrical energy in the light bulb is converted to heat.
  - Some of the heat energy in a heating element is converted to light.

Throughout all these energy transformations, the total amount of energy remains the same.

CONCLUSION

To sum up, let’s look at the production of electrical energy in a battery to illustrate several energy transformations. When chemical changes take place in the electrolyte solution in the battery, the energy released causes negative charges to increase on one plate and positive charges to increase on the other plate.

The electrons have the potential to move through the wires and do electrical work such as running the lights. But this energy is stored until the circuit is connected or the lights are turned on.

The potential energy changes to kinetic energy when the electrons are free to move in the wires. The kinetic energy is used to create light and heat in the light bulbs of the circuit.

The generation of electricity at a hydro-electric dam also illustrates the way potential energy is converted to motion. When water is contained behind a dam, the force of gravity exerts pressure on the water. This force creates potential or stored energy in the water.

If the dam is opened, the potential energy of the water changes to kinetic or moving energy as the water moves through the turbines. The kinetic energy of the water is used to generate electrical energy. The electrical energy is stored in wires as potential energy. This potential is used to do work, or create motion, when an electrical appliance is started.

Throughout all these energy changes, no new energy is created or destroyed. The available energy is only transformed from one form to another.

Answer the following questions about potential and kinetic energy by putting the correct word in the blank. Answers are on the last page.

1. Anything that changes or tries to change the motion of an object is called a _____________ .

2. Kinetic energy is the energy due to the ________________ of an object.

3. Energy that is stored to be released at a later time is called ________________ energy.

4. The units of force and weight (the force of gravity) are the same. The unit of both force and weight in the metric system is the __________________ .

5. Work is force exerted over a distance. The unit of both work and energy is the __________ .

6. Say two cranes do the same amount of work in lifting a load. However, the first machine lifts the load at a faster rate. The first machine has more ______________ than the second machine.

7. When a ball is first thrown upwards, its ___________________ energy is at a maximum and its _______________ energy is at a minimum.

8. When electrical energy is converted to mechanical energy in a power tool, not all the energy is available to do useful work. Some of the energy is converted to _____________ and sound in the machine because of friction.

9. Energy is never used up; it just gets _______________ from one form to another.

10. Choose the best answer.
    If a ball is thrown upwards with 30 joules of energy, at the points halfway up and half way down, its potential and kinetic energy are:
    - a) unbalanced.
    - b) each 15 joules.
    - c) each 0 joules.

ANSWER PAGE

1. force
2. motion
3. potential
4. newton
5. joule
6. power
7. kinetic, potential
8. heat
9. transformed, changed or converted
10. b) each 15 joules